NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3073

EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS

PURE BENDING

By Floyd R. Schlechte and Richard Rosecrans

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

Bending tests were made on a cylindrical semimonocoque shell of circular cross section. The cylinder was tested without a cutout and then with a rectangular cutout which was successively enlarged through six sizes varying from 30° to 130° in circumference and from 1 to 2 bays in length. Strain measurements were made with resistance-type wire strain gages near the cutout on the stringers, the skin, and the rings for each size of cutout, and the stresses obtained are presented in tables.

INTRODUCTION

An experimental investigation of stresses in a semimonocoque circular cylinder with a cutout was discussed in reference 1 which gave results of the tests involving pure torsional loading. Another phase of the cylinder test is given in the present report, which contains stress data for the same cylinder loaded in pure bending with the cutout on the tension side of the cylinder.

Earlier experimental work on cylinders loaded in pure bending is given in references 2 to 4 where stringer strains and a limited number of shear strains are presented for a series of pure-bending tests of cylinders with cutouts.

TEST SPECIMEN AND PROCEDURE

Although the test specimen was the same one as that used in reference 1, a description of the cylinder is repeated here for completeness of the present paper. The test cylinder, which is shown in figure 1, consisted of a 24S-T aluminum-alloy sheet covering of 0.051 inch in thickness, 36 external 3/4 × 3/4 × 3/32 angle stringers of cross-sectional area of 0.1373 square inches, and 8 equally spaced, 24S-T aluminum-alloy Z-section rings of cross-sectional area of 0.4413 square inches. The rings were made of 1/8-inch sheet and were 2 inches deep with 1-inch flanges. The moment of inertia of the cylinder about a diameter was calculated to be 1119.3 in.^4. After an initial test of the cylinder without a cutout, the series of cutout tests was begun with a cutout 1 bay in length by 30° in circumference. In four succeeding tests, the cutouts were 1 bay long and varied up to 130° in circumference. A final test was made with a cutout which was 2 bays long by 130° in circumference. The size of the cutout for each test is given in table 1.

The test procedure was analogous to that used in the torsion tests of reference 1. The cylinder was mounted on a heavy ring which was bolted to a rigid support. Load was applied to a steel bulkhead at the tip by means of a hydraulic jack acting on a loading frame. (See fig. 2.) In this figure, the cylinder is shown with the cutout sidewise, but for all tests included in the present report the cutout was down.

Baldwin SR-4 wire strain gages mounted near the cutout on the stringers, skin, and rings were used for obtaining all of the strain measurements. Type A-12 gages were used on the stringers and rings and AR-1 rosette gages were used on the skin. Typical gage mountings are shown in figure 3. Stringer gages were mounted either at the rings or halfway between rings along the inside corner of the stringer angle. Rosette gages were mounted either halfway between rings or $1\frac{1}{4}$ inches from a ring. In each rosette, two gages mounted at angles of 45° and 135° to the axis of the cylinder were used to measure the shear strain. Ring gages were placed near the neutral axis of the ring and on both flanges. The gage pattern in figure 4(a) shows the location of all the strain gages used in tests 2 to 6. The angular coordinate θ is measured from the center line of the cutout. All the gages shown were used in the test with a 30° cutout 1 bay long. For successive tests with a cutout 1 bay long, the cutout was enlarged by removing panels symmetrically located on either side of the longitudinal center line. All gages not cut away by enlarging the cutout were used in the next test. The gage pattern for test 7, with a 130° cutout 2 bays long is shown in figure 4(b).

In each test, the maximum load was chosen to make the most highly strained gage indicate tension or compression of about 10,000 psi. This was well below the buckling load in each test but was considered high enough to avoid the large relative errors associated with measurements of very small strains.

About 300 or 400 gages were read in each test, but the equipment available permitted only 80 gages to be read at one time. The procedure was as follows: A group of approximately 80 gages was read at each of four successively higher loads; then the first load was repeated as a check. If for some gages the original reading and the check reading differed by more than about 100 psi, the data for those gages were rejected and a test was performed for those gages only. Testing continued until satisfactory checks were obtained. If the temperature varied more than 1° F during a test run, the entire run was repeated. The reruns required only a small portion of the total testing time. After satisfactory data were obtained for a group of gages, another set of about 80 gages was read and the testing continued until all the gages had been read.

DATA REDUCTION AND ACCURACY

For each test, load was plotted against strain for the data from each gage, and the slope of a straight line through the test points determined the value taken as the strain at the maximum test load. Strains were converted to stresses with Young's modulus taken as 10,600,000 psi and the shear modulus as 4,000,000 psi. Tension is considered positive for normal stresses, and positive shear stresses are those that would be produced by a clockwise tip torque.

All results were referred to one quadrant because of symmetry; consequently, when possible, data from gages in various quadrants were averaged. The strain-gage layouts as shown in figure 4 indicate how much averaging was possible. The final stresses were all reduced to correspond to a bending moment of 180,000 in-lb, which was the maximum load for test 7.

Errors in measuring the applied load include an uncertainty of 1 percent in the jack load and a small amount of friction in the loading frame. In addition, the strain gages may have inaccuracies of 200 psi at the loads used in the tests or 3 percent, whichever value is larger. However, the agreement between results in four quadrants indicated that the strain-gage errors were usually considerably less than these amounts, and the results presented are better than individual gage data because of the averaging.

RESULTS

Stresses obtained for the six cutout tests are presented in tables 2 to 7, and the actual maximum load used in each test is also given.

Stringer stresses are given in part (a) of each table. An initial test of the cylinder without a cutout showed that the stresses were very close to values determined by elementary theory. Consequently, in all of the cutout tests, "stringer stresses due to cutout only" were calculated by subtracting the normal stress for no cutout, as determined by ordinary beam theory, from the measured stringer stresses. "Stringer stresses due to cutout only" are presented in part (b) of each table; shear stresses are given in parts (c); and the ring stresses are contained in parts (d).

General trends of the stringer stresses and shear stresses around the cutout are shown pictorially in figures 5 and 6. Stresses corresponding to the 30° cutout are given in figure 5 and stresses for the 90° cutout are given in figure 6. Each figure has three parts corresponding to sections (a), (b), and (c) of the tables. The test points, which are represented by the height of the heavy vertical lines, are joined by straight lines to give a pictorial view of the stress field. In the figures showing shear stresses, the lines joining points on opposite sides of the coaming stringer near the cutout have been broken because a straight line is not very accurate in this region.

CONCLUDING REMARKS

Stresses obtained in a series of pure-bending tests of a stiffened cylindrical shell with a cutout are presented in tables for six different sizes of the cutout. The data presented are intended primarily to serve as a check on methods of analysis or as a guide to the development of such methods. Consequently, no attempt has been made in this paper to interpret the data or draw conclusions therefrom.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., Dec. 10, 1953.

REFERENCES

1. Schlechte, Floyd R., and Rosecrans, Richard: Experimental Stress Analysis of Stiffened Cylinders With Cutouts - Pure Torsion. NACA TN 3039, 1953.

2. Hoff, N. J., and Boley, Bruno A.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. I - Experimental Investigation of Cylinders With a Symmetric Cutout Subjected to Pure Bending. NACA TN 1013, 1946.

3. Hoff, N. J., Boley, Bruno A., and Viggiano, Louis R.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. IV - Pure Bending Tests of Cylinders With Side Cutout. NACA TN 1264, 1948.

4. Hoff, N. J., Boley, Bruno A., and Mele, Joseph J.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. VII - Experimental Investigation of Cylinders Having Either Long Bottom Cutouts or Series of Side Cutouts. NACA TN 1962, 1949.

TABLE 1.- CUTOUT SIZE

Test number	Length of cutout, bays	Width of cutout, deg
1	None	None
2	1	30
3	1	50
4	1	70
5	1	90
6	1	130
7	2	130

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 480,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	1,089		2,024	
15	3,935	3,465	2,373		2,096	
	2,942	2,837	2,506		2,094	
	2,504	2,377	2,287		2,021	
45	1,976	1,972	1,964		1,842	
	1,586	1,579	1,586		1,558	
	1,188	1,117	1,160	1,162	1,173	
75	716	777	787		795	
	-167	-96	-157	-119	-93	
105						

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 480,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 0	6	12	18	24	30
		-2,430	-1,341		-406	
15	1,569	1,099	7		-270	
	713	608	277		-135	
	481	354	264		-2	
45	218	214	206		84	
	148	141	148		120	
	114	43	86	88	99	
75	37	98	108		116	
	5	66	5	43	69	
105						

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 480,000 INCH-POUNDS) - Continued

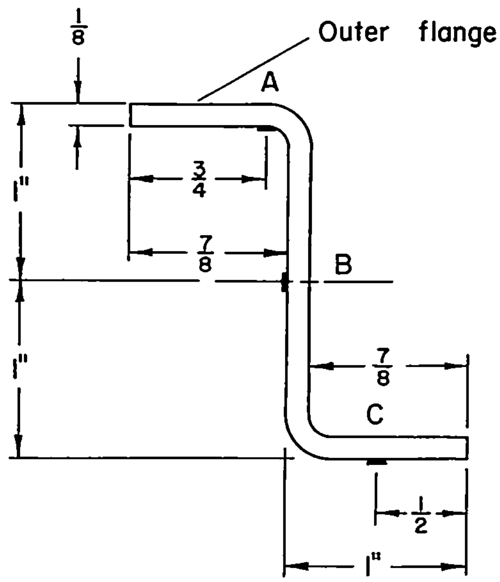
(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0		6	12		18	24	30	36
			25	34					
			1,422	787			114		76
15									
	-19	181	282	538					
	34	-153	76	125			127		153
	15	-93	-19	-53					
45									
	-15	-51	-45	-104		35	41		137
	-5	-49	-53	-147					
	-3	-23	-31	-94	-104	-12	-38		-91
75									
	20	-30	-13		-51				
	22	12	-4	-32	-6	31	-82		-167
105									
	26	23	-90		57				
135									
	65	28	-11				-5		
			-15						
165									
	48	43							

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 480,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	-64	-401	-437
15	-283	-413	-161
25	-204	-230	15
35	-182	-55	40
45	-220	-66	138
55	-218	15	152
65	-205	21	147
75	-163	18	84
85	-113	0	0
95	0	0	0

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 360,000 INCH-POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	12	18	24	30
		0	574		1,654	
15		0	1,104		1,917	
	5,024	4,668	2,820		1,993	
	3,504	3,453	2,892		2,099	
45	2,650	2,667	2,484		2,054	
	2,014	2,022	1,990		1,740	
	1,415	1,442	1,424	1,463	1,412	
75	869	930	936		1,020	
	-192	-35	-148	0	24	
105						

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 360,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		-2,430	-1,856		-776	
15		-2,366	-1,262		-449	
	2,795	2,439	591		-236	
	1,481	1,430	869		76	
45	892	909	726		296	
	576	584	552		302	
	341	368	350	389	338	
75	190	251	257		341	
	-30	127	14	162	186	
105						

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 360,000 INCH-POUNDS) - Continued

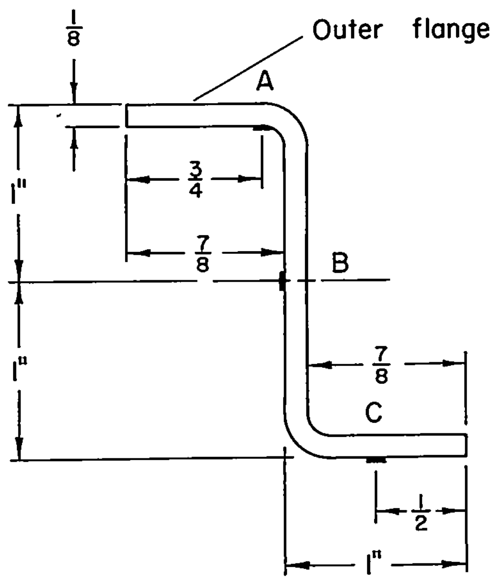
(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			24	29					
			562	710			237		84
15			2,068	1,395					
	27	184	322	628			350		286
	68	-200	-41	-3					
45	-12	-92	-148	-238		107	93		227
	27	-97	-209	-330					
	-21	-52	-163	-258	-266	-65	-99		-78
75	-21	-55	-146		-185				
	4	12	-29	-56	-33	-49	-119		-192
105									
	0	31	11		-64				
135	52	25	10				27		
			0						
165	41	47							

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 360,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	118	-800	-882
15	218	-501	-705
25	-134	-362	-104
35	-220	-10	234
45	-286	146	412
55	-368	216	484
65	-414	226	492
75	-380	143	390
85	-285	114	289
95	-210	72	156

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 300,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	358		1,221	
15		0	454		1,452	
		0	1,060		1,762	
	6,449	5,939	3,428		1,961	
45	4,147	4,013	3,375		2,211	
	2,875	2,846	2,659		2,090	
	1,908	1,932	1,952	1,867	1,715	
75	1,183	1,225	1,288		1,326	
	-57	50	-64	254	226	
105						

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 300,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 0	6	12	18	24	30
		-2,430	-2,072		-1,209	
15		-2,366	-1,912		-914	
		-2,229	-1,169		-467	
	4,426	3,916	1,405		-62	
45	2,389	2,255	1,617		453	
	1,437	1,408	1,221		652	
	834	858	878	793	641	
75	504	546	609		647	
	105	212	98	416	388	
105						

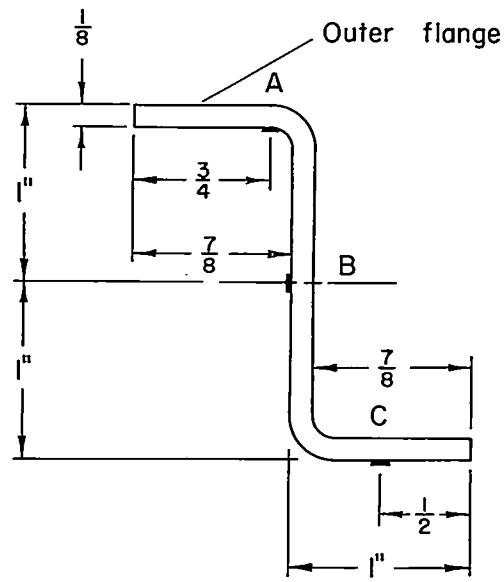
TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 300,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 0	6	6	12	18	18	24	30	36
			7	7					
			394	476			326		185
15			870	1,056					
			2,641	1,634			570		424
	148	297	167	578					
45									
	-49	-208	-236	-222		215	262		363
	22	-204	-408	-596					
	20	-122	-383	-480	-480	-119	-12		-47
75									
	25	-59	-344		-433				
	15	7	-117	-155	-96	-115	-230		-309
105									
	5	17	6		84				
135									
	27	42	17				-20		
			-57						
165									
	42	74							

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 300,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	463	-1,208	-1,442
15	401	-910	-1,160
25	331	-393	-641
35	-324	-88	292
45	-433	350	709
55	-569	521	900
65	-679	515	960
75	-673	376	814
85	-572	310	634
95	-355	149	394

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 240,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.					
	0	6	12	18	24	30
		0	175		848	
15		0	265		1,044	
		0	437		1,362	
		0	1,286		1,852	
45	7,791	7,233	3,975		2,131	
	4,690	4,610	3,808		2,332	
	2,806	3,011	2,918	2,461	2,168	
75	1,678	1,880	1,896		1,761	
	24	283	56	493	532	
105						

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 240,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		-2,430	-2,255		-1,582	
15		-2,366	-2,101		-1,322	
		-2,229	-1,792		-867	
		-2,023	-737		-171	
45	6,033	5,475	2,217		373	
	3,252	3,172	2,370		894	
	1,732	1,937	1,844	1,387	1,094	
75	999	1,201	1,217		1,082	
	186	445	218	655	694	
105						

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 240,000 INCH-POUNDS) - Continued

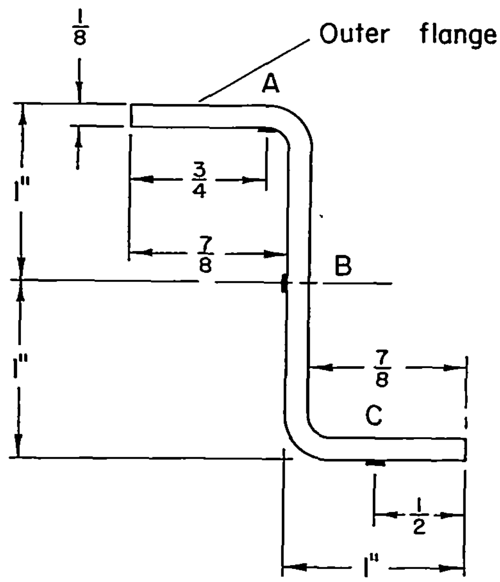
(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			56	9					
			314	269			309		210
15									
			597	658					
			1,094	1,251			791		587
			3,088	1,826					
45									
	-15	358	-55	461		601	560		541
	154	-346	-576	-525					
	83	-243	-645	-732	-677	-94	-124		34
75									
	62	-122	-618		-649				
	12	-25	-275	-315	-269	-244	-411		-420
105									
	0	0	-40		90				
135									
	31	25	53				-22		
			83						
165									
	77	62							

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 240,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	1,002	-1,491	-1,956
15	755	-1,192	-1,598
25	489	-713	-973
35	181	-10	-202
45	-662	226	896
55	-826	694	1,371
65	-908	884	1,546
75	-1,035	656	1,455
85	-922	592	1,171
95	-730	358	837

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	-11		257	
15		0	71		410	
		0	156		661	
		0	368		1,120	
45		0	618		1,682	
		0	1,852		2,424	
	10,918	10,346	5,448	3,334	2,675	
75	5,936	5,973	4,982		2,751	
	1,166	1,617	1,299	1,993	1,744	
105						

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		-2,430	-2,441		-2,173	
15		-2,366	-2,295		-1,956	
		-2,229	-2,073		-1,568	
		-2,023	-1,655		-903	
45		-1,758	-1,140		-76	
		-1,438	414		986	
	9,844	9,272	4,374	2,260	1,601	
75	5,257	5,294	4,303		2,072	
	1,328	1,779	1,461	2,155	1,906	
105						

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Continued

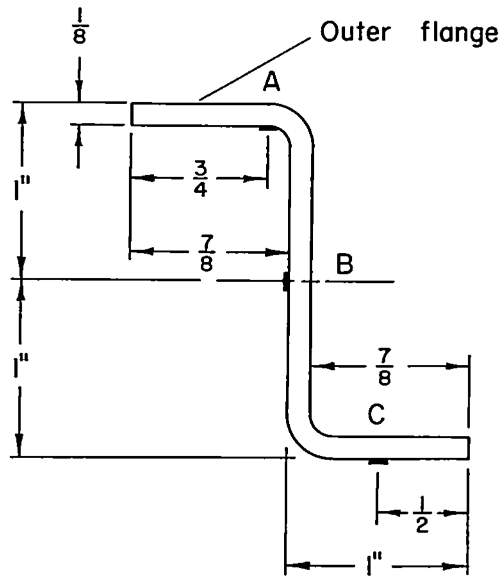
(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			47	-25					
			152	11			293		346
15									
			242	58					
			443	345			758		859
			719	754					
45									
			1,323	1,568		1,139	1,030		943
			4,056	2,212					
	-140	379	-483	375	350	542	408		371
75									
	-81	-476	-1,224		-820				
	-37	-169	-974	-1,046	-1,009	-667	-680		-531
105									
	-70	-49	-422		-321				
135									
	16	-33	29				140		
			194						
165									
	41	-4							

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	1,877	-1,804	-2,793
15	1,592	-1,516	-2,454
25	1,172	-1,214	-1,894
35	392	-684	-935
45	-368	-132	167
55	-734	959	1,208
65	-1,842	1,219	2,682
75	-1,945	1,537	3,037
85	-1,852	1,644	2,833
95	-1,614	1,290	2,292

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
			0	0		127
15			0	35		297
			0	127		625
			0	293		996
45			0	599		1,643
			0	1,639		2,236
	9,394	9,476	9,119	5,070	3,254	2,650
75	5,989	5,986	5,830	4,839		2,883
	1,579	1,712	1,876	1,797	2,067	1,908
105						

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
			-2,430	-2,430		-2,303
15			-2,366	-2,331		-2,069
			-2,229	-2,102		-1,604
			-2,023	-1,730		-1,027
45			-1,758	-1,159		-115
			-1,438	201		798
	8,320	8,402	8,045	3,996	2,180	1,576
75	5,310	5,307	5,151	4,160		2,204
	1,741	1,874	2,038	1,959	2,229	2,070
105						

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Continued

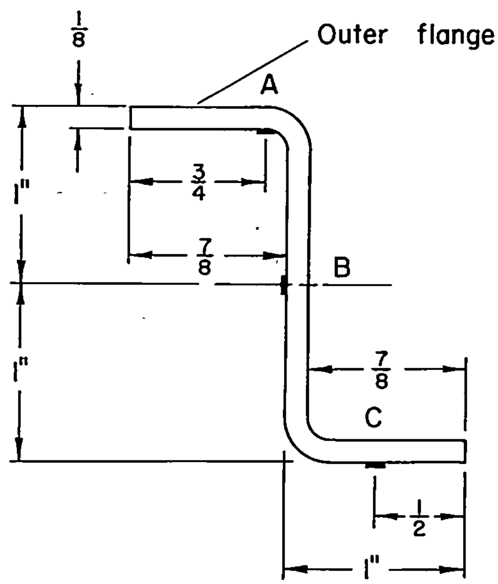
(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	12	12	18	24	24	30
				-124	8			
15				99	22			449
				247	37			
				389	271			989
45				641	628			
				1,187	1,464		1,051	789
				3,693				
75	-118	231	672	-132	511	503	616	433
	164	21	-206	-865		-581		
105	84	-14	-177	-931	-1,030	-976	-663	-836
	-21	0	-190	-507		-412		
135	-144	-136	-148		-66			
165	-202							
		-21	-8					

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT, 180,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	1,961	-1,913	-2,856
15	1,696	-1,579	-2,544
25	1,128	-1,372	-1,881
35	498	-806	-1,034
45	-400	-90	180
55	-858	854	1,208
65	-2,242	1,018	2,750
75	-1,898	1,564	3,140
85	-2,008	1,558	2,740
95	-1,696	1,314	2,722

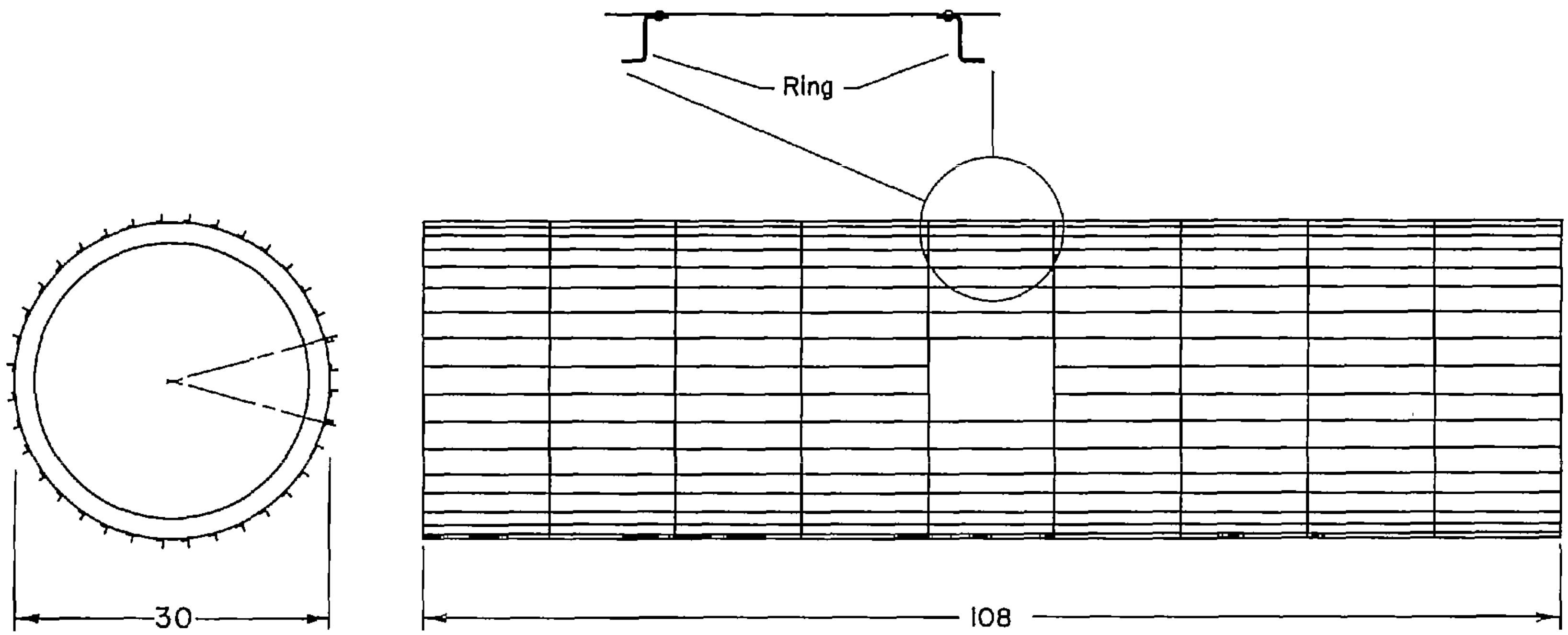


Figure 1. - Test specimen.

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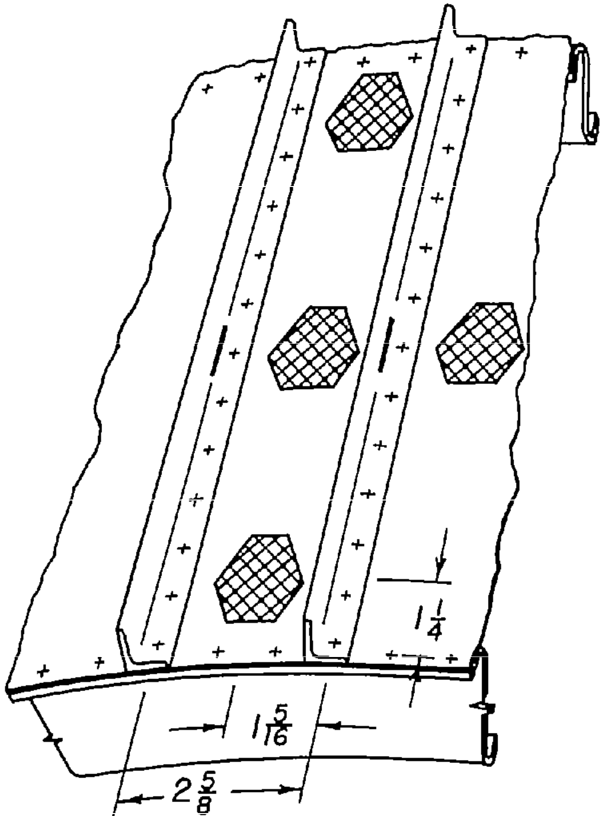
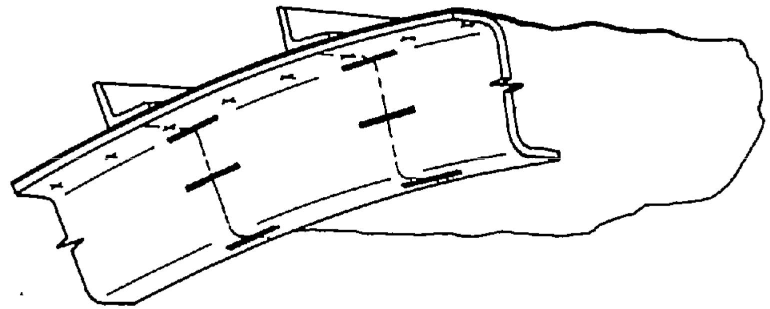
Figure 2. - Loading system.

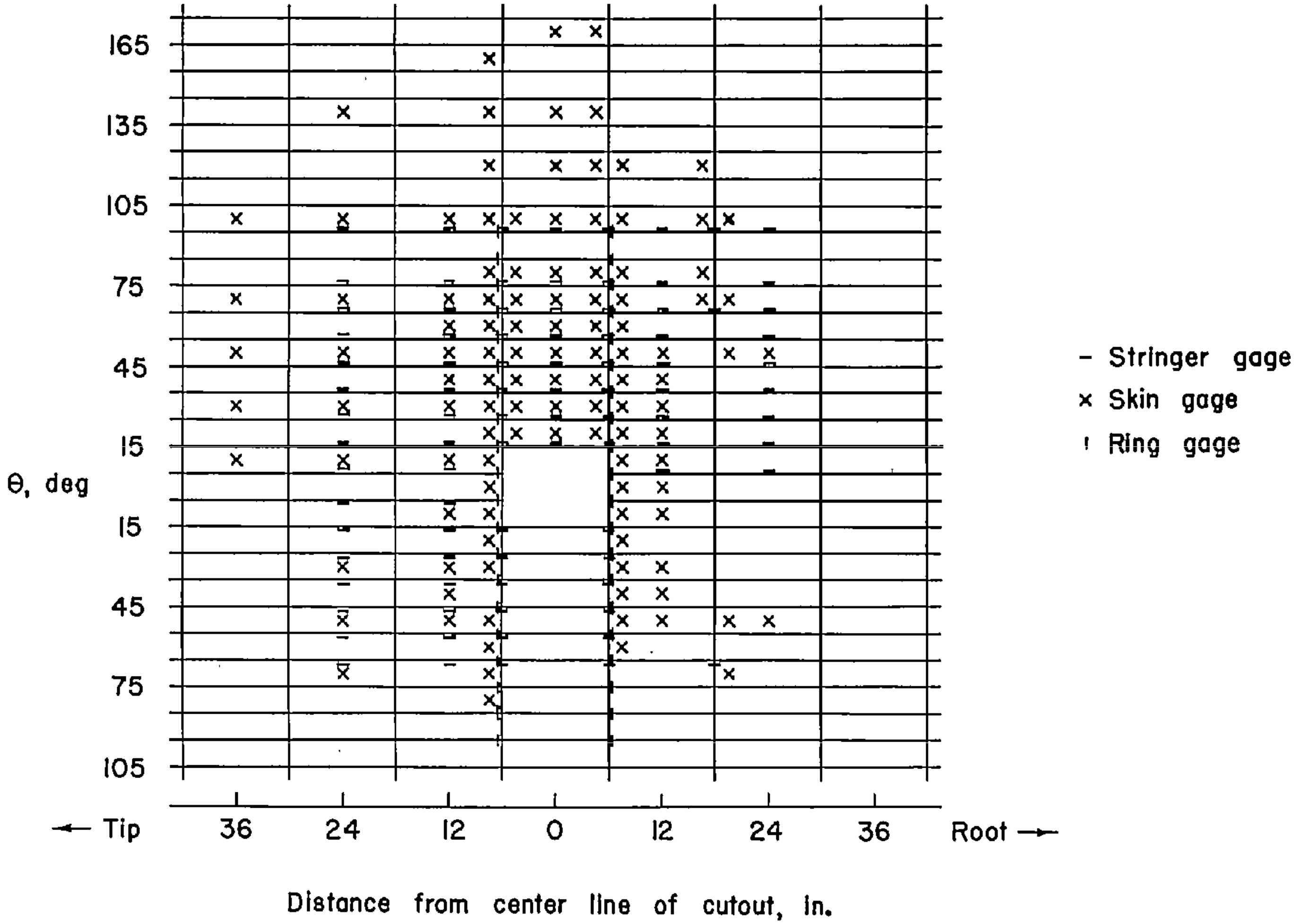


(a) Stringer and skin gages.



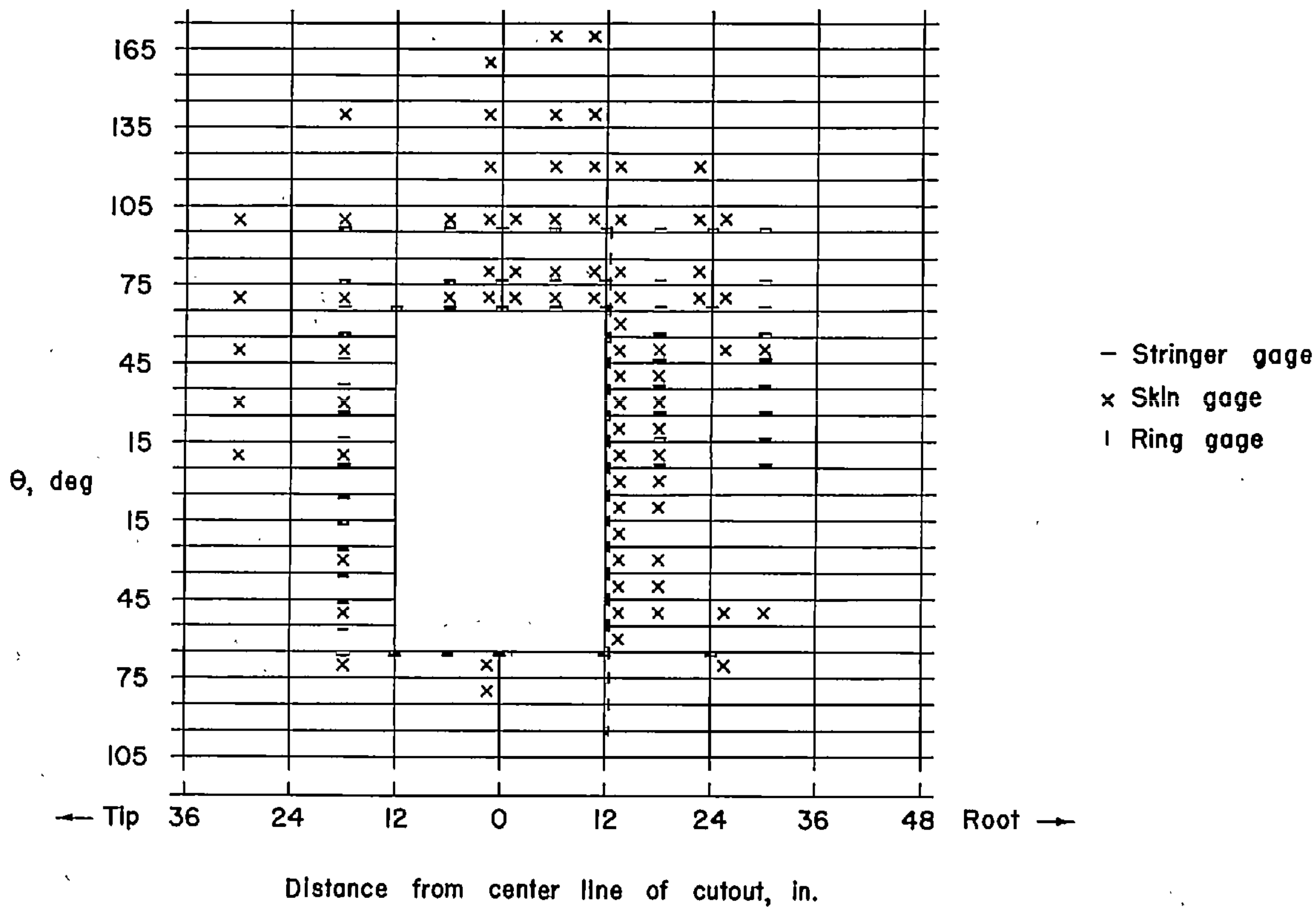
(b) Ring gages.

Figure 3. - Typical gage mountings.



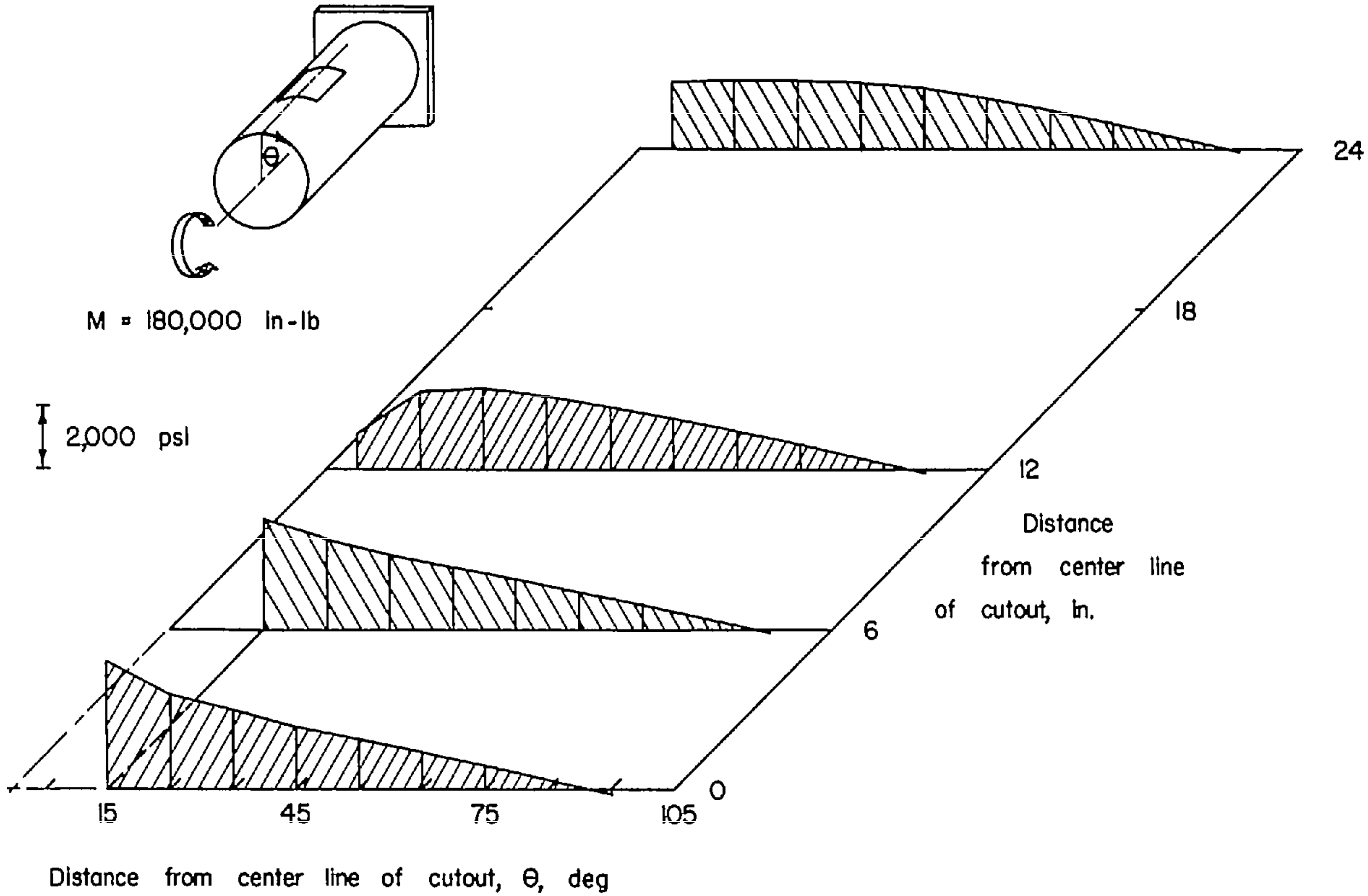
(a) Cutout 1 bay long.

Figure 4.-Gage pattern.



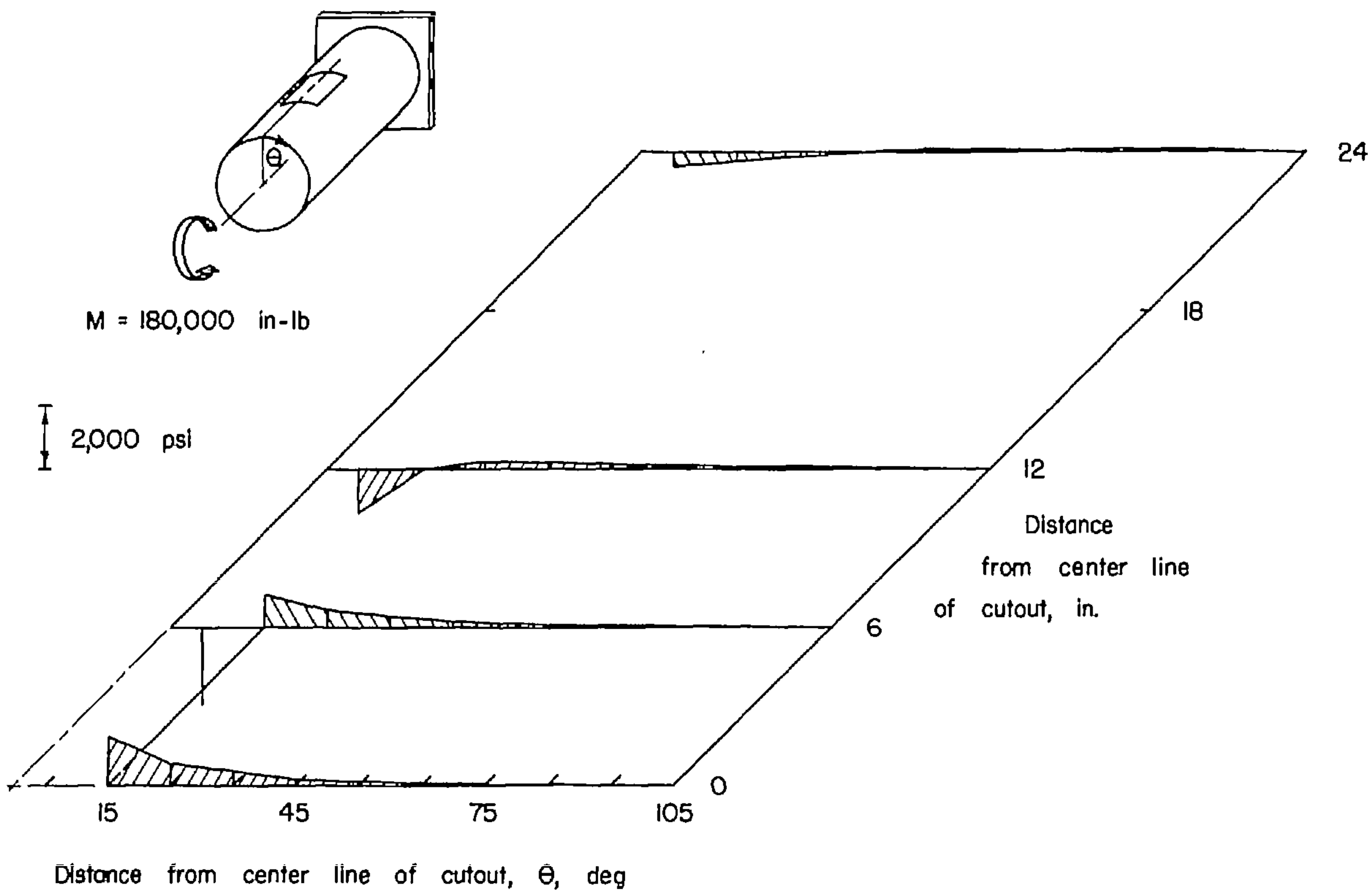
(b) Cutout 2 bays long.

Figure 4.- Concluded.



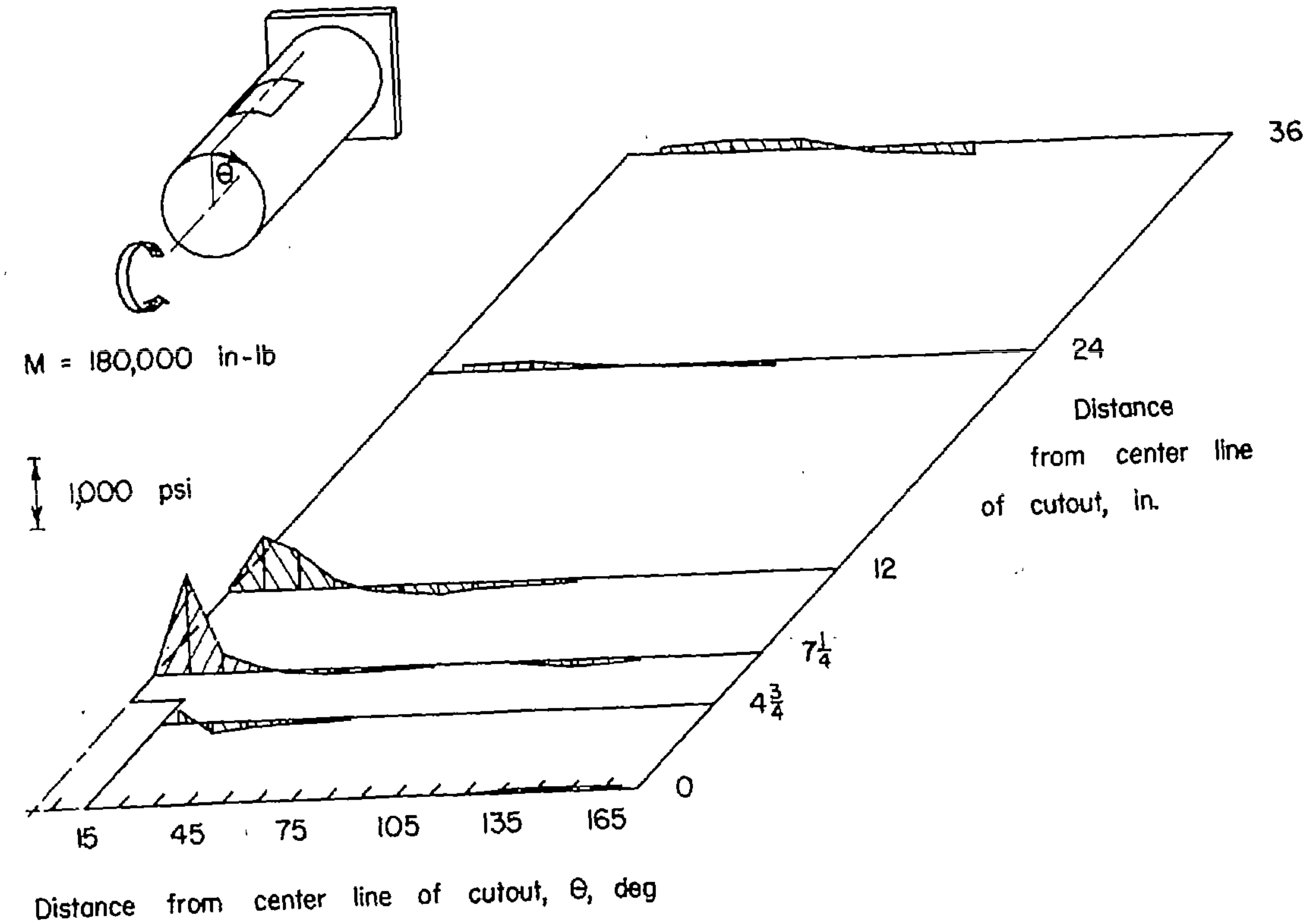
(a) Stringer stresses.

Figure 5.- Stress distribution, 30° cutout.



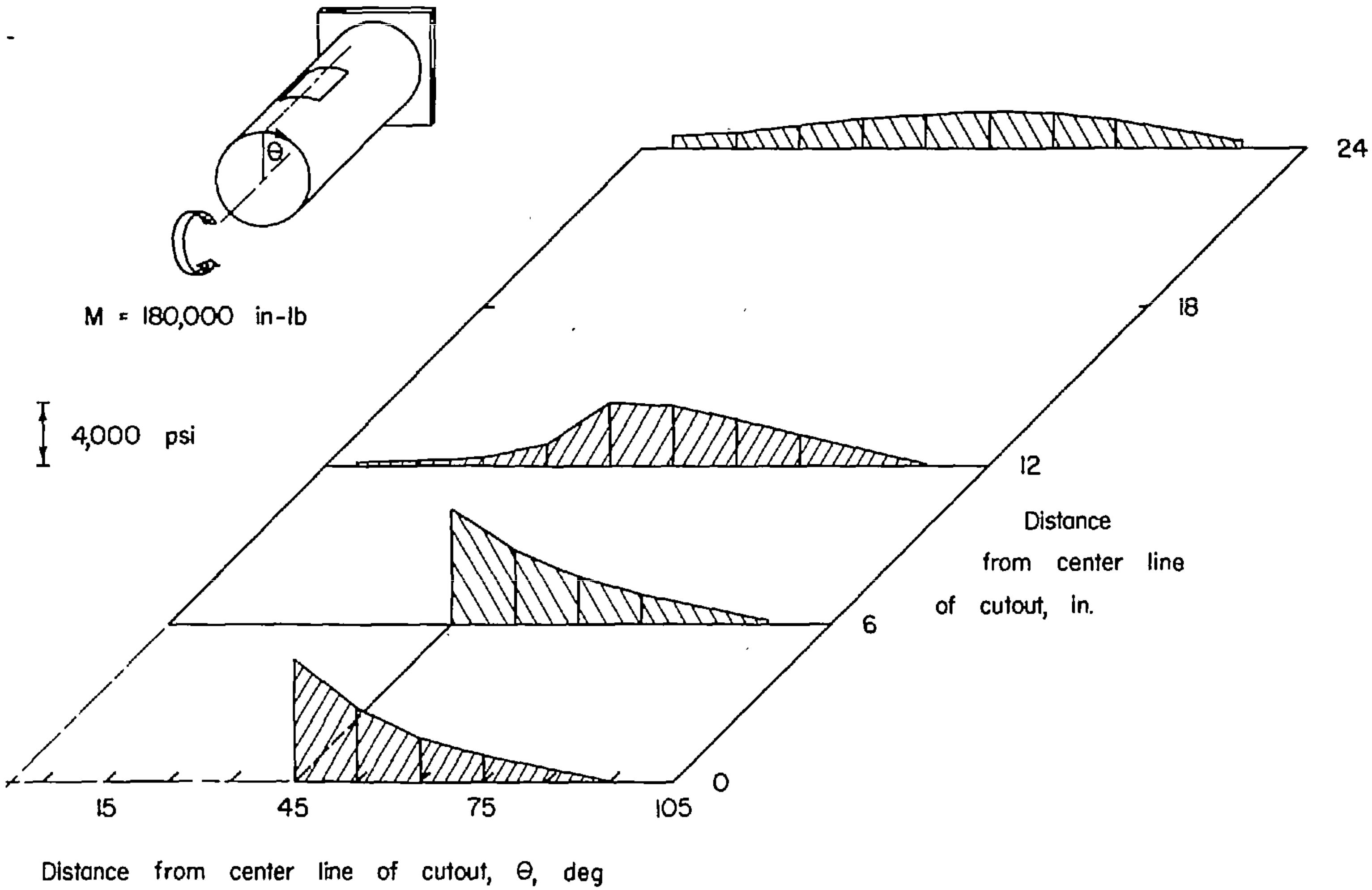
(b) Stringer stresses due to cutout only.

Figure 5. - Continued.



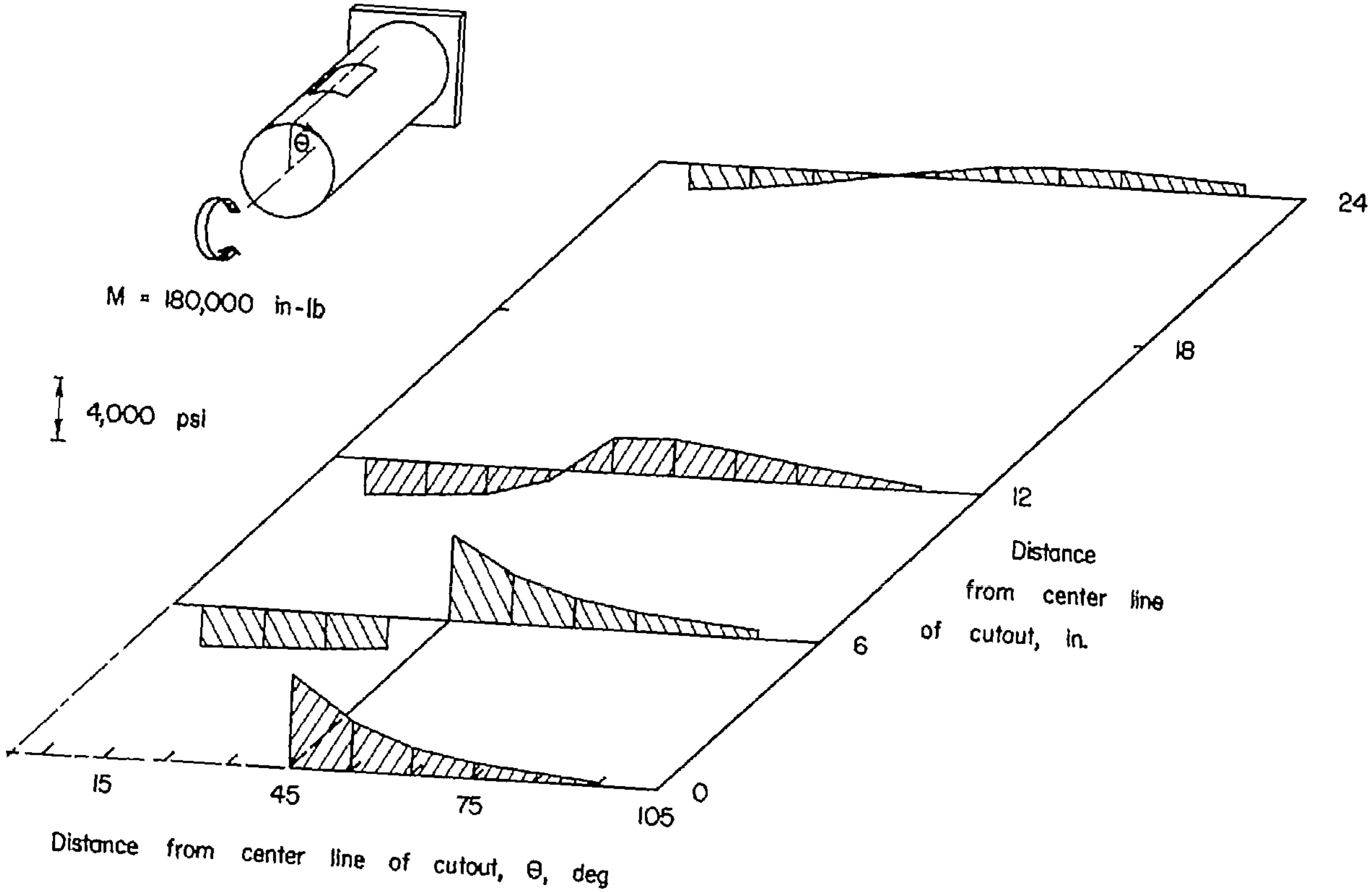
(c) Shear stresses.

Figure 5. - Concluded.



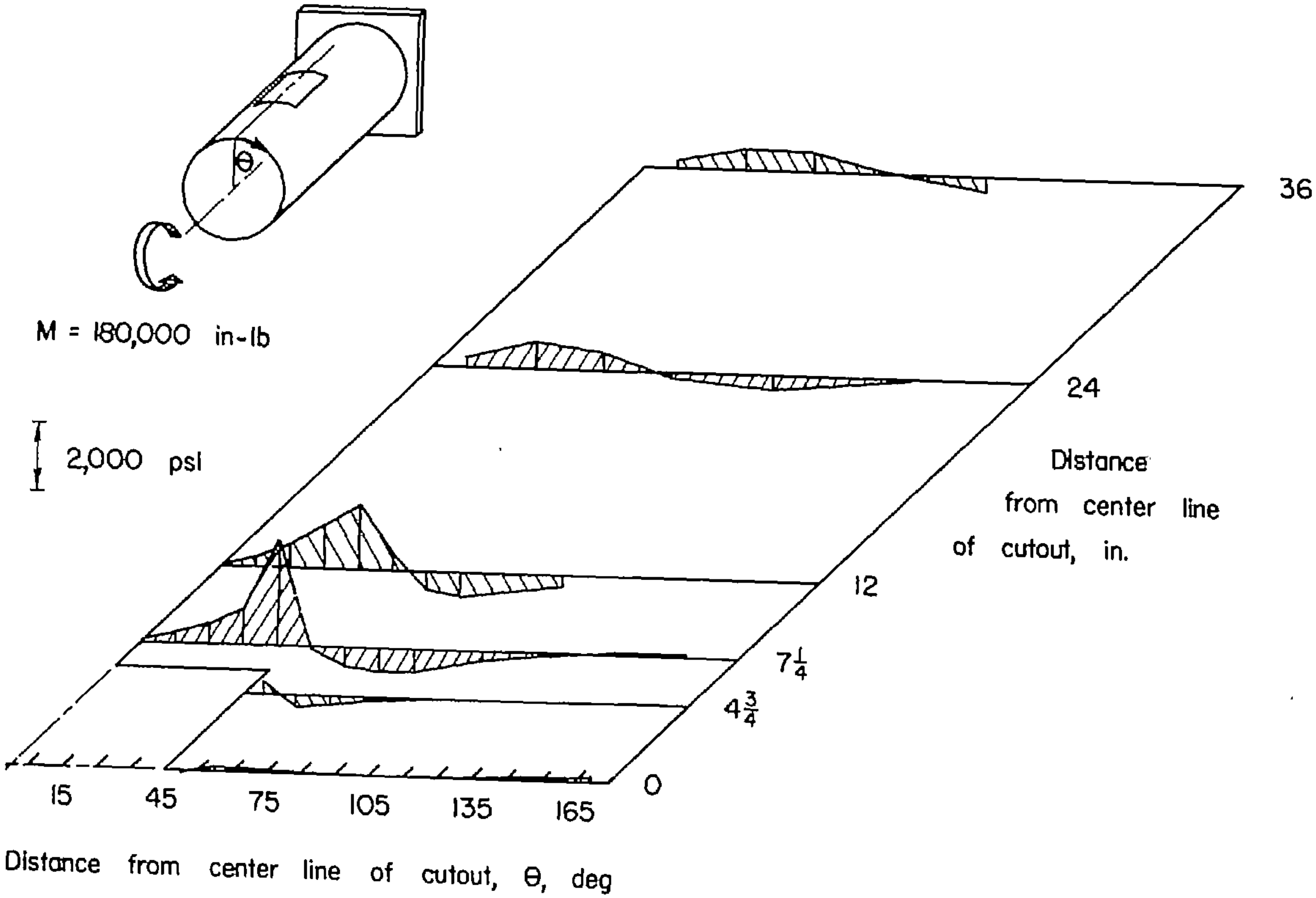
(a) Stringer stresses.

Figure 6.- Stress distribution, 90° cutout.



(b) Stringer stresses due to cutout only.

Figure 6. - Continued.



(c) Shear stresses.

Figure 6. - Concluded.

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